Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

1.932
A2M93
no.19

LIBRARY
RECEIVED
★ MAR 1 1940 ★
U. S. Department of Agriculture

Mimeographed Circular Series (ACE-19)

REPORT OF RESEARCH WORK IN CORN STORAGE

Presented before the Farm Structures Division at the fall meeting of the American Society of Agricultural Engineers, at Chicago, Illinois, December 5, 1939.

By H. J. Barre

This paper discusses some phases of the storage of both ear and shelled corn particularly as to structural and ventilation requirements. Some of the findings of recent investigations on corn storage and a brief discussion of problems needing further study are also incorporated.

The problem of storage. Although the storage of ear corn on the farm has been practiced for years, the problems connected therewith became more fully appreciated when attempts were made to formulate recommendations for proper storage in connection with the loan provisions of the Agricultural Adjustment Act. New factors, including early picking and the growing of later maturing varieties of hybrid corn in areas of shorter growing seasons, have no doubt aggravated the problem. The merits of the various ventilating features of different types of cribs and ventilators still are not well understood.

Not until the fall of 1938 was the storage of dry shelled corn in tight bins tried on an extensive scale. Many who had had experience with storage in tight bins felt that difficulties would be experienced with the beginning of warm weather in the spring during the so-called "germination period."

Scope of Storage Investigations. A number of Agricultural Experiment Stations in the corn belt have studied corn storage for a number of years to a limited extent. In 1937 the U. S. Department of Agriculture in cooperation with the Illinois and Iowa agricultural experiment stations inaugurated experimental studies at field stations at Urbana, Ill., and Ames, Iowa. A Bankhead-Jones Project was organized a year later at the request of the Agricultural Adjustment Administration in an attempt to find what types of cribs and what storage

practices are most successful in conditioning and maintaining quality of corn stored on farms. Agencies cooperating included the Weather Bureau, Agricultural Adjustment Administration, Bureau of Plant Industry, Bureau of Agricultural Economics, and Bureau of Agricultural Chemistry and Engineering, and the agricultural experiment stations of Minnesota, Indiana, Illinois, and Iowa.

At the field stations, observations have been made on the performance of different types of cribs with various ventilation features. The cribs at Urbana are mounted on wheels for moving on and off scales in determining moisture losses. At Ames, the investigators used a large crib and granary divided into various isolated sections to represent certain types of construction. Several steel cribs loaned by manufacturers have been erected at the Agricultural Engineering Research Farm at that station and filled with ear corn to determine which features have merit in drying corn. Significant results have been obtained and some of these will be discussed below under the appropriate headings.

In the fall of 1938 ear corn from the 1937 crop in nearly 300 cribs was inspected. Samples of corn were obtained by the use of improved sampling probes developed in co-operation with the manufacturer. These samples were examined for moisture content, damaged kernels and other grade factors. The survey covered counties in Iowa, Minnesota and Indiana where farmers were having storage difficulties.

Later in the fall an inspection of different types of cribs was continued in 11 counties in representative areas in Indiana, Illinois, Minnesota, and Iowa. The inspection included 194 cribs with 1938 ear corn, 25 with 1937 ear corn, and 20 bins with 1937 shelled corn. Samples were obtained at intervals of about six weeks from certain representative portions of each crib and bin. Grade determinations were made on all samples and, in addition, fat acidity, germination and

kernel damage determinations were made on selected samples.

With the storage of large quantities of shelled corn in steel bins by the Commodity Credit Corporation, the condition and temperature of corn in steel bins is being observed periodically in a number of counties in each of the States named above.

Ventilation Requirements for Storage of Ear Corn. Since the problem of storing ear corn is largely one of reducing the excess moisture to make it safe for subsequent storage as either ear or shelled corn, maximum ventilation is essential to permit drying at every opportunity when the weather is favorable. It is often cribbed at a moisture content higher than 20 percent in the northern parts of the Corn Belt. In the colder areas in the Corn Belt most of the drying takes place in the spring months as shown in fig. 1 based on observations of corn in cribs in Northern Iowa. Some drying may also take place in the fall if the weather is warm and otherwise favorable. Very little, if any, drying will take place during the winter months, in fact, corn may take up moisture during these months if the fall is drier than usual.

One is impressed by the need for ventilation when the amount of moisture to be removed from ear corn is considered. For example, in order to reduce the moisture content of a bushel of ear corn from 20 to 13 percent, a total of nearly 9 pounds of moisture, almost half of which is in the cobs, must be removed. Hence, in the drying of 1000 bushels of ear corn from 20 to 13 percent, about 4 1/2 tons or over 1000 gallons of water must be removed. In this respect the storage of ear corn differs radically from that of other grains such as wheat, where ordinarily the moisture reduction necessary to make it safe for storage is only a few per cent or 1 to 2 pounds per bushel.

Before proceeding to discuss the various crib characteristics which aid in ventilation it might be well to consider the rate of drying of high moisture ear corn which could be expected under fully exposed conditions, i.e., under conditions of maximum ventilation. Observations of weights of ears fully exposed to air under a shelter at both Ames and Urbana, showed that they lose moisture from five to ten times as fast as ear corn in a crib 8 feet wide. This large difference is primarily due to differences in the amount of ventilation. If the same air conditions could be maintained about each ear in a crib as that about the exposed ears, all the ears should dry just as fast as the fully exposed ears. Only by a free air movement in all parts of the crib can this condition be approached.

Figure 2 shows the moisture content of groups of 3 and 48 ears exposed to air under a shelter at Ames for a period of about 10 months beginning in January 1939. These observed moistures are of interest and value in indicating in general the moisture content to which corn may be expected to dry in a crib for this locality at different times during the year. In other words, they show the limitations imposed by weather on the moisture content. Another very important item not shown by this graph is the rate at which the ears will approach the equilibrium moisture content, that is, where the ears as a whole are in equilibrium with the moisture of the air. While space does not permit going further into this discussion, the fact is that the rate at which the moisture content of ears change is much more rapid in summer than in winter. The magnitude of the much larger daily fluctuations during the summer indicates to some extent the greater rate of change in warm weather.

Crib Characteristics. The most important dimension of a crib as an aid in promoting ventilation is its width. Experiments with cribs of different widths

have shown that corn in a crib 6 feet wide will dry more more rapidly than that in a crib 8 feet wide, and that the corn in a crib 8 feet wide will dry more rapidly than in one 10 feet wide. The additional resistance to the movement of air provided by the thicker mass of corn accounts, in all probability, for the slower rate of drying in the wider cribs.

In view of the above, it is apparent why the practice of storing high moisture corn in a driveway is particularly objectionable. The crib shown in fig. 3 with corn stored in the full length of the driveway is virtually a crib 27 feet in width, rather than one about 7 or 8 feet wide as it should be. The ventilation through the corn in the outer cribs, as well as that in the driveway, is impaired and unless the moisture content is much lower than usual at the time the corn is placed in storage, spoilage is likely to occur even if horizontal ventilators are used in the corn in the driveway.

Certain maximum widths of cribs are recommended for different localities in the corn belt in consideration of the maturity of the corn and the prevailing weather conditions during the first six months of storage. Temperature and humidity of the air, sunshine, amount of wind and average date of killing frost all have a bearing on the amount of ventilation needed, and determine the width of crib to use. Fig. 4 indicates recommended maximum widths of rectangular cribs for various localities.

The height to which the wall should be slatted is somewhat of a question. Experiments with cribs having walls slatted 1/4, 1/2 and full height above the floor showed that the last type is desirable for promoting rapid drying; in these the amount of spoilage was also less. In the crib slatted 1/4 the height, the damage was considerably greater in the upper half. There appears to be no merit, in the case of single cribs of moderate height, in extending the tight siding down

farther than a few feet below the eaves to prevent snow from blowing on top of the corn after it has settled.

The ventilation of cribs having either a tight wall or an enclosed lean to shed on one side is considerably impaired. There is much less opportunity for air to move through the corn as in the case of a crib open on both sides.

Exposure of a crib to prevailing drying winds is important. The double crib in fig. 5 partly protected and shaded by the grove of trees is an illustration of inadequate exposure of the crib to the prevailing winds and the sun. This condition combined with the fact that the doors were kept closed during the spring was likely responsible for grade 4 corn in one crib and sample grade in the other, although the moisture content in early December was only 19 percent.

The results of experiments with ventilators indicate that they are not as effective as ordinarily believed, although they have been recommended generally to improve ventilation in case the corn is high in moisture content or the crib is too wide. What types of ventilators are most effective remains to be determined by further investigation.

During the past year or two a number of double cribs with only a 6-inch ventilator through the center have been built similar to the one shown in fig. 6. Although its location within 2 feet of a large crib has probably been partly responsible for the slow drying of the corn on each side of the narrow ventilator, undoubtedly the slow drying was primarily due to the lack of ventilation. Ordinarily the corn next to the west wall dries more rapidly and is of a lower moisture content than that next to the east wall, but in this crib the conditions were reversed.

Ventilation Requirements for Storage of Shelled Corn. As indicated above, the storage of shelled corn differs radically from that of ear corn. Ear corn

will dry a good deal if properly cribbed, while shelled corn will dry little, if any, in a tight bin and therefore must be dry when stored. A moisture content of not more than 13 to 13 1/2 percent is required for safe storage of shelled corn.

Since dry shelled corn with less than 13 to 13 1/2 percent moisture will not heat, unless possibly when badly infested with insects, there is no occasion for ventilation, except where it might aid in maintaining cooler temperatures in under as near the roof of a steel bin. Ventilation is undesirable under the roof in winter since the surface layer of corn will actually take up moisture from the air. Hence roof ventilators and other openings should be closed in winter; this will not only aid in preventing the taking up of moisture, but will also prevent the possiblity of snow blowing in.

The storage of damp corn, as well as that of damp wheat, requires some means of ventilation to remove the moisture and the excessive heat generated by the corn through respiration. Since the microorganisms are inactive at low temperatures and heating is therefore not likely to present a problem in cold weather, it is possible to store shelled corn of a relatively high moisture content for a limited time. The problems and limitations in connection with the storage of damp corn need further investigation.

Weathertightness of Cribs. Although the walls of most types of cribs are relatively open and there is some opportunity for rain water and snow to get into the corn especially in that next to the wall, the most essential part of a crib, insofar as weathertightness is concerned, is a tight roof. A survey of cribs made in September 1938, showed that the roofs of an appreciable number of cribs were in poor condition. Probings of the corn in such cribs often revealed moldy and at times wet kernels, a condition not to be expected at that time of the year. In several cribs having roofs in poor condition, holes had been eaten through the

shingles, either by rats or squirrels, similar to that shown in fig. 7.

Preventing snow from blowing into the crib on top of the corn is very desirable in Northern and Western areas of the corn belt; this may be accomplished with tight siding extending below the eaves to a line which will be below the level of the corn after settling. Since snow will also drift in through the slatted walls and sometimes several feet into the corn, it is desirable to locate the cribs where they will be somewhat protected from the north and west winds. For this reason cribs in northern areas are usually located on the south side of a driveway and grain bins, sheds, and other units are located on the north side. Since corn usually takes up moisture during the winter and because of the hazard of drifting snow there is some merit in having the crib incorporated in a building that can be closed during unfavorable weather. Observations of cribs so located showed the corn to be from 2 to 3 percent drier than that in exposed cribs.

Weathertightness of Bins for Shelled Corn. Experience during the first year of government loans on shelled corn showed that the entrance of either rain water or snow as practically the major cause for storage difficulties. Even with unusually dry grain, a bad roof leak or two will cause some of the grain to spoil. The spoiled portion tends to make the adjacent grain musty and may cause it to heat. As indicated above all openings, including those of the ventilator, should be closed during the winter to avoid any possible entry of snow. Although a roof may be rain-tight, it is often difficult to make it snow-tight.

Ear Corn Pressures. Cribs filled with ear corn are subjected to loads and pressures much greater than ordinarily supposed. Observations made by McCalmont and Ashby several years ago showed that a crib 8 feet wide without cross ties or braces the portion of the total weight of corn carried by the floor at various

depths is as follows:

Depth (feet)	Proporation (percent)
8	72
12	68
16	64
24	52

In cribs having cross braces, less weight is carried by the floor, since an appreciable part of the weight is carried by the braces.

The outward and downward pressures on the wall with and without cross braces in a crib 8 feet in width were found in the above investigations to be as follows:

Depth below surface (ft.)	Without Cross Braces		With Cross Braces	
	Outward (lbs./ft.^{2})	Downward	Outward (lbs./ft.^{2})	Downward
8	62	41	58	38
12	79	50	70	45
16	91	58	81	50
20	100	61	88	51

The outward pressures in cribs 10 and 12 feet wide at the same depths were estimated to be 25 and 50 percent greater, respectively, than those given in the above table. In the 8 foot crib with corn 24 feet deep about 1/3 of the total weight was carried by the cross braces, which were spaced from 5 to 6 feet apart.

Although the ear corn settled after filling, there was a relatively small increase in the weight on the braces after filling. The distribution of the total weight of the 24 feet of ear corn in the crib with cross braces was about as follows: 45 percent carried by the floor, 20 percent by the wall through friction;

and 35 percent, by the braces. For example, the outward and downward pressures which have to be carried by one stud in a crib 14 feet high, with studs spaced 2 feet apart and cross braces 4 feet apart, are 1400 and 950 pounds, respectively. In addition, the studs to which the braces are fastened have to support a vertical load from the brace of about 2000 pounds. The cross brace is called upon to resist an outward pull of about 2000 pounds.

Field observations and experience have shown that unless cribs are designed to withstand these rather large loads and pressures with a reasonable degree of safety, failures are sure to occur, with the result that the life of the building as well as the period of usefulness is considerably impaired. In cribs of other than the circular type, cross bracing which is an economical method of resisting the outward pressures, has always presented a problem, largely because of the weight the braces must carry in addition to resisting the outward pressures. In frame cribs the cross brace of three 1-by 12-inch boards, shown in fig. 8, has been very satisfactory where the total depth of the corn is not more than 16 feet. This type has maximum strength for carrying a vertical load, in addition to a much larger surface for nailing to the studs, than can be obtained, for example, by a 2-by 6-inch piece. These braces are ordinarily spaced 4 feet apart.

Cross ties of wire or steel rods are usually undesirable, because the weight of the ear corn will break them, or they will draw the wall in at the points where they are anchored. Frequently, the stud is broken or cut into by wire because of insufficient bearing surface. Ties do not provide the necessary cross bracing of the building when the cribs are empty and the overhead bins are loaded.

Obviously one of the disadvantages in the pole type of crib is the inability to anchor braces with nails satisfactorily. The 1 by 12 inch cross braces in the pole crib in fig. 9 had torn loose from the poles due to the weight of the corn on the braces. Probably the most satisfactory method of tying a pole crib together

is by means of rods or strands of wire, each protected by a plank of sufficient strength for the purpose of carrying the weight of corn above the tie.

Shelled Corn Pressures. Inasmuch as no pressure measurements had been made on shelled corn, pressure panels were installed in the doors of two 2000 bushel cylindrical steel bins at Webster City, Iowa, to determine the pressures exerted by shelled corn (fig. 10). These bins were filled with corn having a moisture content of about 11 percent. One bin was filled to a depth of about 11 feet and the other, 10 ft.; they contained about 2300 and 2000 bushels, respectively.

The preliminary observations showed that at a depth of 10 feet the outward pressure is about 210 lbs./ft.^{2}, while the downward pressure at this depth is about 80 lbs./ft.^{2}, (fig. 11). In other words, the outward pressure at a depth of 10 feet would produce a tension of about 1900 pounds in a foot wide horizontal strip of wall of the bin which was 18 feet in diameter. From an average value for the downward pressure of about 40 lbs./ft.^{2} the bin wall, 10'-8" high, carries a total load of about 24,100 lbs., or almost 19 percent of the total weight of the corn. By comparing these outward pressures with those of ear corn it will be noted that the pressure of shelled corn is about 3 times that of ear corn. Hence, additional bracing or tying is needed in cribs which are to be used for storing shelled corn, as has been done by a number of farmers this fall. Pressures from wheat appear to be somewhat less.

In answering numerous inquiries as to how a bin, garage, shed or similar building about 8 feet in height might best be tied or braced, the recommendation has been made to supply tie rods mid-height along the length as well as across the building. Four by six-inch stays through which the tie rods would be fastened were recommended in order to give support to each stud in the building. The studs in a large number of these buildings were only 2 by 4's, but a check

on the stresses showed these to be ample. Bracing and tying a building in this manner is much better than using 2 by 6-inch ties every four feet.

Cribbing Practices. In view of the fact that picking with a machine is more satisfactory earlier in the season and losses in the field are likely to be less, the tendency is to start picking early. However, these advantages may be more than offset by the better quality of the stored corn after it has become drier. A few observations made to date indicate that relatively high moisture corn placed in storage is likely to be damaged by mold a few weeks after cribbing, providing warm weather prevails. High temperatures stimulate the activity of microorganisms even though the weather may be unusually favorable for drying.

In case of one of the cribs filled with 1937 corn which showed an unusual amount of damage, the farmer started picking as early as September 20 and finished by October 1. The object in starting early was to complete picking before his neighbor, who owned the picker, started to pick.

This fall a few well ventilated cribs were filled experimentally during the latter part of September in order to obtain high moisture corn. After a few weeks of storage, an appreciable amount of mold was noted and the damage was rapidly increased during the warm weather, although the weather was unusually dry. The damage of the corn under the filling spout where there was a considerable collection of husks and shelled corn was decidedly greater than elsewhere. It should perhaps be mentioned that these conditions were observed in cribs as narrow as 6 1/2 feet wide and otherwise provided with good ventilation features.

There is less opportunity for damage to take place when damp corn is cribbed in cold weather, since microorganisms producing mold are relatively inactive at low temperatures. Also, there is opportunity for high moisture-corn

stored in winter to lose some moisture before warm weather occurs.

Rodent Damage. Rat damage in varying degrees was evident in nearly every crib inspected in the surveys. The extent of damage in many cribs was a good deal more than expected. It was rather unusual to probe a crib and not find some rat stools in each of the individual probings. The upper layers of corn were frequently found to be infested as well as the lower portions of corn. As pointed out above rats had frequently eaten holes in the roofs to permit them to obtain water more readily. Some farms were conspicuously free from rats, indicating that they can be controlled by proper measures.

Not infrequently, a crib badly infested with rats and one with practically no evidence of rat damage were found on the same farm. In the infested crib the floow was built close to the ground which encouraged rats to harbor underneath and there was ample opportunity for rats to get in and out of the crib. The floor of the other crib was higher above the ground. Creosote-treated timbers and treated wood floors appeared to be effective in preventing damage.

Phases of Storage Needing Further Attention. Before concluding this discussion it might be well to summarize a few phases of corn storage which need further attention.

1. Ventilation Requirements of Cribs. The requirements of cribs as to ventilation in areas where high-moisture corn occurs and where weather is less favorable for drying are not well known. More definite answers to such questions as the following should be obtained: What are the relative merits of floor and wall ventilation, roof and crib ventilators? At what maximum moisture contents can grains be conditioned satisfactorily under the different prevailing weather conditions? What are the merits of natural, controlled, and mechanical ventilation?

2. Relation of Weather to Storage. The relation of weather to the successful storage of ear corn in particular has not been given the attention it deserves. The limitations as to the moisture content to which corn will dry under natural ventilation and the rate at which corn approaches this moisture content are governed by the prevailing weather and should be evaluated for various areas. It is rather doubtful that under extreme conditions of immature corn and unfavorable weather for drying, storage difficulties can be avoided altogether even in the better ventilated structures.

3. Shelled Corn Pressures. Although there is available limited data as to the pressures of shelled corn and other grains, the behavior of these pressures under certain conditions is not known. For example, does the downward pressure by friction continue to exist on the wall of a steel bin when placed on a gravel fill and the wall is permitted to settle? What are the stresses introduced in bins when emptied from the bottom at one side or a corner?

4. Insect Control. The experiences with control of insects by fumigation in storage of shelled corn are limited. The frequency of fumigation to insure against infestations should be evaluated for shelled corn and for different areas in the corn belt.

5. Shelled Corn Storage. In view of the importance of the storage of shelled corn, observations should be made on the change in the soundness of corn stored over a period of 2 to 3 years. Does this vary with the moisture content and quality? Is the loss of dry matter appreciable? Does it vary with different areas?

Legends for Illustrations

Fig. 1. Observations of the moisture content of 1938 ear corn in the center and two sides of a single crib.

Fig. 2. Observations of the moisture content of exposed ears at Ames, Iowa, 1939.

Fig. 3. The storage in the driveway of corn having only moderately high moisture content is contrary to good storage practice. The ventilation of the corn in the cribs on each side is considerably impaired. (Same as fig. 2 in report "A Survey of Farm Storage of Corn", October 1938).

Fig. 4. Map showing recommended maximum widths for rectangular cribs in the commercial corn area. (Same as fig. 2 in Bulletin on "Corn Storage in the Ever-Normal Granary".)

Fig. 5. The protection of this crib from both wind and sunshine by the trees and closed doors to the driveway was likely responsible for spoiled corn in this crib.

Fig. 6. Double crib with 6 inch ventilator through the center.

Fig. 7. Damage to a roof by rats.

Fig. 8. Simple cross brace of 1-by 12-inch boards in a rectangular crib.

Fig. 9. The 1 x 12 inch cross braces in this new pole crib failed shortly after filling.

Fig. 10. Two steel bins at Webster City in which pressure panels have been installed in the door opening.

Fig. 11. Downward and outward pressures in two 2000 bushel steel bins filled with shelled corn.